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ALFRED

MICROWAVE AMPLIFIER

MODEL 529 , Serial No. 22

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MICROWAVE AMPLIFIER
MODEL 529

SPECIFICATIONS

Frequency Range:	4 to 8 Gc.
Power Output	10 watts.
Spurious Modulation:	40 db minimum @ 0 dbm in.
Gain(at rated power output):	30 db minimum.
Gain(small signal @ 0 dbm in):	35 db minimum.
Gain Adjustment:	0 to 25 db gain reduction at 0 dbm in by adjustment of front panel GAIN-POWER control from maximum to minimum.
Modulation:	Greater than 25 db gain variation by 300 volts external pulse.
RF Impedance:	50 ohms.
Connectors:	
RF	Type N female receptacle, front panel.
EXT MOD	Type BNC, front panel.
Metering:	Helix current, and Collector current on 4" front panel meter, selected by front panel switch. Helix, anode, and cathode tip jacks are available at rear for checking with external precision voltmeter.
Front Panel Controls:	GAIN-POWER (maximum to minimum setting). HELIX voltage (MIN. to MAX.) METER current switch.
Power Supply:	All TW tube electrode voltages, and solenoid current are regulated. Protective relay shuts off TW tube power upon helix overcurrent.
Input Voltage:	105 to 125 volts, 50/60 cps.
Physical:	Bench, with perforated metal dust cover. Handle sides are removable to permit mounting in a standard 19" rack.

	Height: 12 1/4" Width: 19" Depth: 16" from panel, 17 1/2" overall
Finish:	Panel, grey hammertone. Sides, top, and bottom, dark metallic grey.
Weight:	71 pounds.

SECTION 1 - GENERAL

1-1 DESCRIPTION

The ALFRED Model 529 Microwave Amplifier is a stable, high gain broadband power amplifier of microwave signals in the frequency range of 4 to 8 Gc. It is a compact, versatile instrument consisting of a permanent magnet type traveling wave tube, and power supplies for all required operating voltages. Electrical protection is provided to prevent damage to supply or TW tube from misadjustment or failures. Thus the varied and unique traveling wave tube characteristics may be conveniently applied to laboratory and systems use. Some possible applications are:

1. Power amplification of wide band signal generator outputs of complex modulated RF signals.

2. Amplification of RF pulses with rise times as short as a few millimicroseconds.

3. Isolation of a load from a microwave signal source.

4. Generation of extremely stable microwave oscillations either at fixed frequency or tunable over a wide range, using an external resonant feedback network.

Type N RF power connections can be made at either the front or rear panels. The unit is normally shipped with connectors mounted on the front panel. Rear connections are simply made by remounting the connectors and cables to holes provided in the rear panel.

Panel controls for grid and helix voltages are provided to optimize performance for specific applications. A panel meter with switch monitors either helix or collector current. An overcurrent relay causes shut off of all high voltage should helix current exceed 3 ma for any reason.

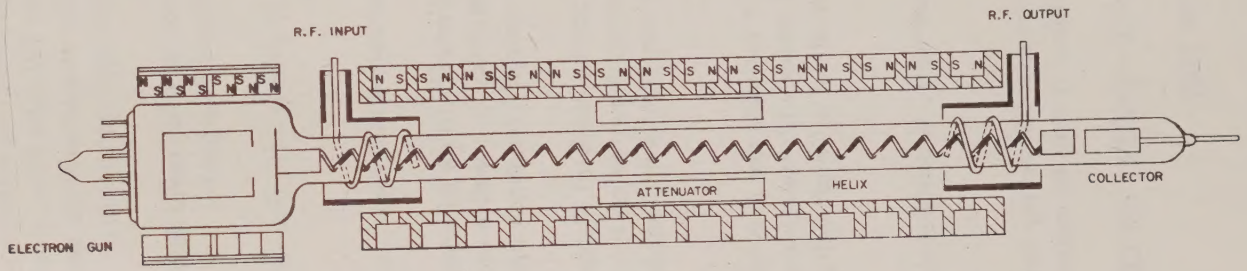
The TW tube requires no RF adjustment, is completely encased for protection, and is easily replaced.

The Model 529 is built as a convenient laboratory bench instrument. However, simply by removal of outside sheet metal sides, it may be mounted in a standard relay rack.

SECTION 2 - THEORY OF OPERATION

2-1 GENERAL DESCRIPTION OF TW TUBE

The traveling wave tube physical arrangement is indicated in Figure 1. The electron gun produces a beam of electrons which travels down the axis of the helical wire coil to the collector. The magnetic flux from the surrounding permanent magnet restricts the beam to travel axially along the tube just inside the helix. RF signals at low impedance are



PPM TRAVELING WAVE TUBE

FIGURE 1

connected to the helix at the electron gun end and travel down the metallic path of the helix. The velocity of the electron beam is critically adjusted by the potential difference of the cathode and helix so that the beam velocity down the axis is just a little faster than the progressive RF signal on the helix. The field of the helix RF signals causes the electrons to bunch so that at the collector end, their increased field returns to the helix an amplified signal which is conducted out to the load. Reflections down the helix are absorbed by the attenuator, consisting of a lossy helix externally placed and positioned between the input and output. Due to the low impedance connections to the helix and the relatively long effective path provided by the TW tube, uniform amplification over a broad band of frequencies is achieved.

A more detailed description of traveling wave tubes and associated pertinent information are presented in the Engineering Notes, at the end of this manual.

2-2 TW TUBE PERFORMANCE CHARACTERISTICS

Gain and Power Output Figure 2 shows typical curves of small signal gain, and maximum power output as a function of frequency. These curves are taken at rated helix voltage. The small signal gain is better than 40 db over the frequency range. Gain at rated and saturated output is greater than 40 db over the same frequency range. Gain-Power attenuation is greater than 25 db by panel control of the grid voltage. Attenuation is greater than 25 db by an external 300 volt pulse to the grid through EXT MOD connector S1.

2-3 RF LOAD

The TW tube may be operated at any collector current up to rated value into an RF load with any voltage standing wave ratio in the rated frequency range. Performance will be stable without spurious oscillations, but output power will be less into mismatched loads.

2-4 POWER SUPPLY

1. A transistor regulated AC heater supply, insulated for full cathode DC voltage, providing 6.3 volts for the TW tube and the heaters of the control amplifier tubes.

2. An electronically regulated Helix, and Collector supply providing voltage from 2900 to 3200 volts with 320 mv peak to peak ripple or less.

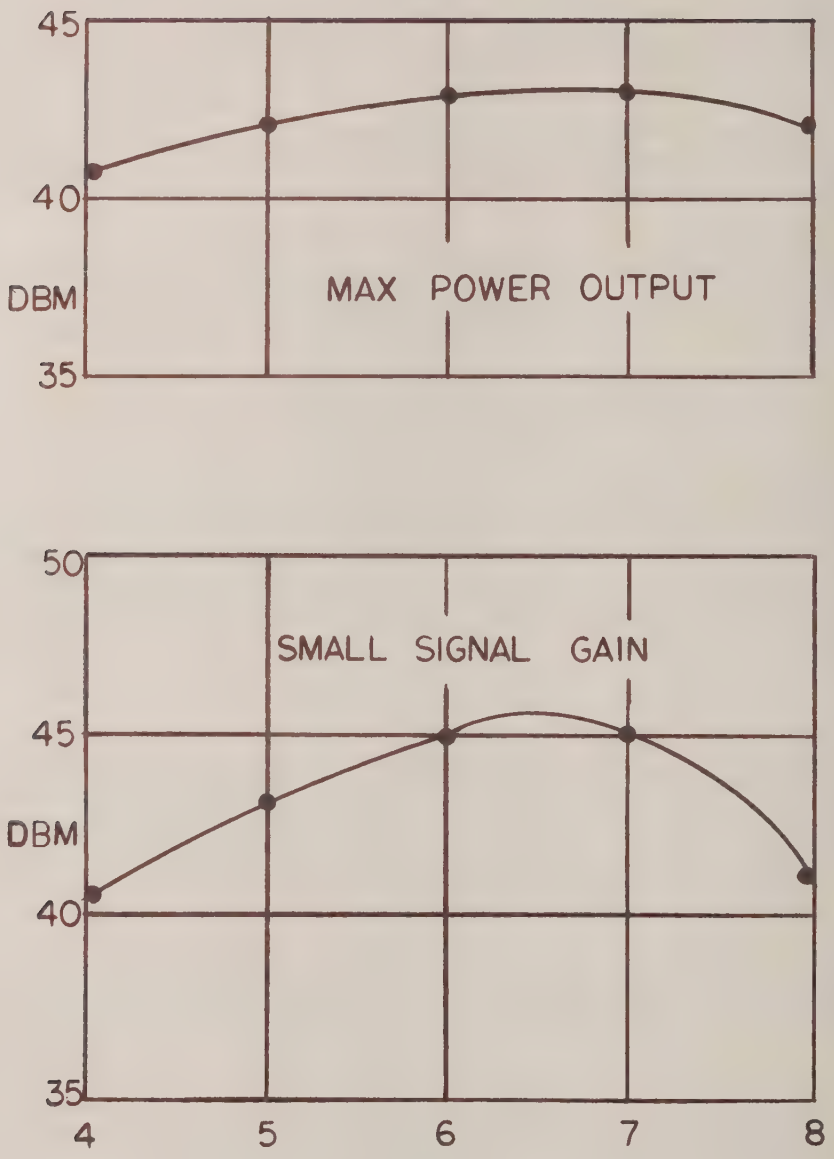
3. A transistor regulated Anode supply providing a fixed 54 volts above helix.

2-5 FUNCTION OF CIRCUITRY

Function of circuitry, see schematic in the rear of this manual. In this manual, reference to panel controls is made with capital letters and underlined, internal or chassis controls is made by capital letters only.

2-6 POWER AND SWITCHING

All power to the instrument is fed through POWER switch SW1. Closing of SW1 energizes



TYPICAL MODEL 529 POWER OUTPUT AND GAIN VS FREQUENCY

FIG. 2

transformer T1 and T3 through POWER fuse F2 to provide filament currents to the TWT and power supply heaters, the 300 volt grid supply, the 56 volt anode and screen supply, and the 200 volt supply required in the helix overcurrent relay K2 circuit. Helix overcurrent relay K2 picks up through tube V9 to place the unit in standby condition. The high voltage circuit powered by transformer T2 through fuse F1 and contacts of relays K1 and K2 may be energized by depressing HV ON switch SW3 to pick up relay K1. Interlock contacts on K1 maintain the circuit when SW3 is released. The high voltage supply is de-energized by depressing HV OFF switch SW2, should overcurrent relay K2 drop out due to excessive helix current.

2-7 LINE REGULATED SUPPLIES 6.3V, 300V, and 56V

Regulation of these supplies is accomplished by regulating the input to the primary of transformer T3. Transistor Q1 is effectively in series with the input transformer T3. Rectifiers CR2 to CR5 are connected in a bridge network to provide DC to the transistor for the positive and negative swings of the AC line. The voltage drop across the transistor automatically adjusts to maintain the primary voltage of T3 essentially constant, independent of line voltage changes. The drop across the transistor is varied by employing Zener diode ZD1 as a stable reference through which changes in output voltage control the net transistor base current. On one half cycle forward transistor emitter to base bias is developed through the 5K resistor R1 and the low forward diode resistance of the Zener. On the other half cycle the bias current is opposed by any output voltage in excess of the Zener breakdown voltage and is developed through the low forward diode resistance of CR1. Biasing is set so that variation of ± 10% maximum from nominal 115 volts rms input, will cause corrective changes in the drop across Q1 for less than ± 3% change in the output. Capacitor C1B serves to average the DC current pulses through the transistor and bypass any AC ripple. C1A operates in the same manner for the base bias current. Taps are provided on the transformer T3 primary to compensate for voltage tolerance of the Zener diode.

2-8 HIGH VOLTAGE SUPPLY

When transformer T2 is energized by depressing the HV ON switch, approximately 3800 volts DC is supplied to the series control tubes, V1, V2, and V3 in parallel from the voltage doubling network of capacitors C5 and C6, rectifiers CR8 to CR16, CR17 to CR25, and winding 1-2 of T2.

The series regulating tubes V1, V2, and V3 in parallel are controlled by amplifier tubes V4 and V5 to provide an electronically regulated supply with a nominal value to 3200 volts. Reference voltage is developed across V6, V7, and V8 and is compared with the supply output voltage at the grids of differential amplifier V5. The amplified difference at the plates of V5 is applied to the cathode and grid of the left half of V4 by employing the right half of V4 as a cathode follower. The difference voltage is further amplified and appears at the plate of V4 left half as a single ended output to drive the grids of the series regulator tubes V1, V2, and V3. The series tubes will conduct more or less as required to reduce the difference in grid voltages to the differential amplifier V5 to zero and thereby maintain the supply output at 3200 volts.

The supply voltage is sampled by a resistor divider network consisting of HELIX CALIB potentiometer R32 and precision resistors R33 through R40 to provide the input to grid (pin 2) of

differential amplifier V5.

The positive side of the supply is connected to ground through meter M1 resistor R63. The capsule and collector of the TW tube are connected to the ground side and the cathode to the -3200 volt side of the supply.

Helix voltage is obtained from the left half or pentode side of V9 acting as a cathode follower. The grid of V9 (pin 7) is connected to front panel HELIX control potentiometer R47 and can be varied from approximately +3 to -400 volts with respect to ground or conversely from +2800 to +3200 volts with respect to TWT cathode. The plate voltage of V9 left half is supplied by T2 winding 4-5 through rectifier CR7 and filter capacitor C4.

HELIX CALIB potentiometer R32 provides compensation for component tolerance variations so that accurate calibration of HELIX control potentiometer R47 can be made.

Helix current through R60 varies the bias on tube V9 right half. When the helix current reaches maximum safe value, the bias is increased sufficiently to cut off the tube and drop out overcurrent relay K2. Contacts of K2 open the high voltage circuit to remove all high voltages from the TWT electrodes. Voltage for the plate of V9 right half and K2 in series is provided by transformer T1 winding 3-4 through resistor R2, rectifier CR6 and filter capacitor C3.

Filaments of series tubes V1, V2 and V3 are connected in series so that failure of one will turn off all and prevent overloading of operative tubes. Heaters of amplifier tubes V4, V5 and overcurrent relay tube V9 are also connected in series so that open circuit on any heater will turn all off, dropping out relay K2 and removing high voltage.

A fixed voltage of approximately 56 volts above the helix voltage (less the small drop due to helix current in R60) is supplied by the +56 volt supply. The +56 volt supply also furnishes the screen voltage for V9 pentode side.

Helix, Anode, and Cathode tip jack connections are provided on the rear of the instrument for external voltage measurements.

Switch SW4 selects either Collector or Helix current to be measured with meter M1. Shunts R63 and R65 provide scale multiplication. During the switching action of SW4 only the meter connections are broken, the shunts remain in their respective circuits so that neither the collector nor the helix circuits are broken during switching.

2-9 EXTERNAL PULSE MOD AND GRID CONTROL

Transformer T3 winding 1-3, diodes CR27 and CR28, capacitors C22 and C23 form a voltage doubling network to provide -300 volts relative to the TWT cathode line. GRID CALIB potentiometer R71 in series with GAIN-POWER control R72 across the supply furnish a variable grid voltage of 0 to approximately -300 volts which is connected to the grid through resistor R73. The GRID CALIB potentiometer R71 provides a range of 0 to -50 volts to permit the setting of the grid electrode voltage at correct value for maximum power output when the GAIN-POWER control is at MAX position.

Both the gain and the power output of a TWT amplifier are dependent upon beam current which in turn may be controlled by the grid electrode voltage. For this reason the grid control potentiometer R72 is marked GAIN-POWER and is panel mounted for ease of operation.

SECTION 3 - INSTALLATION AND OPERATION

3-1 INSTALLATION

Upon receipt carefully unpack and inspect the instrument for damage received from transit. Should any damage be found, follow procedure outlined on "Shipment Damage Claim" page at the end of this manual.

This instrument is designed for either bench or rack operation in normal ambient temperatures. Air flow near the unit should be completely unrestricted. Operation in the presence of very strong magnetic fields should be avoided unless external magnetic shielding is provided. Primary power requirements are 105 to 125 volts, 50 to 60 cps, approximately 500VA. If operation at other voltage or frequency is contemplated, consult manufacturer.

The Model 529 instrument is supplied with grey sheet metal sides containing handles. If the instrument is to be rack mounted, the screws on each handle side except those holding handle, should be taken out and the sides removed. Unit is now ready for inserting into rack. Supports should be provided in the rack to carry the weight of the unit upon its insertion or removal.

CAUTION: The ambient temperatures in the rack near the instrument must be maintained at less than 135° F.

3-2 INITIAL OPERATION

1. Before turning on power, set panel controls:

   GAIN-POWER to MIN.
   HELIX to 3090V.
   METER switch to HELIX

2. Turn on power and allow instrument to warm up at least 5 minutes.

3. Depress HIGH VOLTAGE ON switch.

4. Slowly advance GAIN-POWER control to MAX position. Note that as the control is advanced, helix current should be well below 3 ma.

5. When GAIN-POWER control has been advanced to MAX and HELIX to value specified on tube data sheet with helix current at or below its maximum value, change METER switch to COLLECTOR X20. Current should be at or slightly greater than the operating value of cathode current given on the TW tube data sheet enclosed at the rear of this manual. 55.0 MA.

If current reading is too low GRID CALIB control near top right side of chassis may require resetting. Remove top dust cover for access to control.
CAUTION: Extremely dangerous voltages exist on and near this adjustment. Use extreme care in making the adjustment not to touch any component or hardware mounted on the high voltage board. Turn HIGH VOLTAGE off before loosening or tightening the lock nut on the control. Use a plastic rod with one end shaped to a screw driver point to make the adjustment. Adjust until rated cathode current given on tube data sheet is obtained, alternately checking helix current to assure it remains below maximum value.

6. Apply RF. Input power up to 1 watt will not cause damage. However, only the normally required level of a few milliwatts or less should be used. If RF output can be observed, adjust, if necessary, HELIX voltage slightly for optimum output. See also sub-section following, titled SYNCHRONISM. If RF output cannot be measured, connect an ungrounded 1/2% or better accuracy voltmeter to read helix voltage between HELIX and CATHODE tip jacks at rear of instrument and set HELIX control to give a measured voltage of exactly that specified on TW tube data sheet.

7. METER switch should be left in COLLECTOR X20 position during normal operation. An occasional check of helix current is recommended.

3-3 SYNCHRONISM

When the velocity of the electron stream and the progressive velocity of the RF signal are essentially the same, they are said to be in SYNCHRONISM. When operation at a single frequency is contemplated, helix voltage can be adjusted to synchronous value, to give maximum gain and output at that frequency. When operation over a wide band of frequencie is contemplated, the helix voltage adjustment should be made to the factory determined value. At this setting synchronism usually occurs at some frequency usually near the high end of the band. Even though other frequencies are off synchronism, rated broadband response results.

3-4 REPEAT OPERATION

1. Before turning on power, turn GAIN-POWER control to min.

2. Turn on power and allow 5 minutes warmup.

3. Depress HIGH VOLTAGE ON switch and raise GAIN-POWER control to MAX, or to desired operating level, noting that helix current does not exceed 3 ma and should drop well below this at MAX position. If too high, turn GAIN-POWER to MIN and follow procedure outlined in INITIAL OPERATION, Paragraph 3-2 above, to optimize performance.

3-5 OPERATION AS AN AMPLIFIER

Amplification is linear for RF output up to 6 db below saturation. Further drive beyond this level causes the output to flatten and then decrease. Operation in the region of saturated output is nonlinear, causing appreciable distortion and harmonic content in the output signal.

3-6 OPERATION AS A BUFFER

The Model 529 can very effectively serve to isolate a microwave signal source from a load. Reflections from mismatches, load variations, and the effects of modulation will not appreciably affect the impedance of the input terminals of the amplifier. The attenuator on the TW tube helix provides approximately 55 db attenuation between input and output, so load changes will be isolated from the source by this 55 db attenuation less the gain of the amplifier. The extreme case of a short or open circuit would be to change the VSWR of the amplifier input by about 7%.

3-7 OPERATION AS AN OSCILLATOR

The use of an external feedback circuit involving a passive resonator such as a cavity, will permit use of the TW tube amplifier as an extremely stable fixed frequency or wide range oscillator. Oscillation results when total loop phase shift is in the vicinity of n x 360° producing positive feedback. This is accomplished by careful adjustment of helix voltage. Since helix voltage accelerates the electrons in the beam, it determines their velocity through the helix. Transit time and phase between output and input of the TW tube, therefore, varies with helix voltage. When a continuously adjustable resonator is employed, it is necessary to optimize phase with the HELIX control progressively across the band. Otherwise, a series of oscillation modes will occur as phase of the TW tube amplifier rotates. A directional coupler or non-dissipative attenuator should be employed in the feedback line to minimize amount of output power fed to the input. This reduces harmonics and makes available almost all output power to drive a load.

SECTION 4 - MAINTENANCE

4-1 GENERAL

CAUTION: Extremely dangerous high voltages exist in this instrument. Observe the utmost care when checking or making repairs.

Routine maintenance should consist of the following:

1. Check blower operation every three months or after 1000 hours use, and oil bearings with a few drops of light machine oil. Regular attention to the blower is essential since its failure could result in damage to the TW tube from overheating.
2. Test at regular intervals the power supply tubes to detect marginal performance. Any voltage regulator tubes removed for test should be returned to their original sockets. INTERCHANGING OR REPLACING VOLTAGE REGULATOR TUBES WILL NECESSITATE RECALIBRATION OF HELIX SUPPLY VOLTAGE.

3. As the TW tube ages, preset GRID CALIB control may require readjustment to maintain rated collector current when panel GAIN-POWER control is at MAX.

4-2 CALIBRATION OF HELIX SUPPLY VOLTAGE

Calibration of helix supply voltage is accomplished by connecting an ungrounded voltmeter having 1/2% accuracy or better to the Helix Voltage test points on rear of the unit. Unlock the HELIX CALIB control, located near the right top side of chassis. With TWT disconnected, move panel HELIX control over entire range and note readings. Adjust HELIX CALIB control so that voltage indications are within ±2% for any setting. Lock HELIX CALIB control.

4-3 TROUBLE SHOOTING

Should a failure occur, follow a logical procedure to locate the cause. Refer, if necessary to the THEORY OF OPERATION section and the schematic diagram included in this manual. Blown fuses should be replaced with 250 volts, type 3AG.

Power supply tubes can be observed to determine if heaters are operating and voltage regulator tubes lit, by removing screws holding top dust cover and sliding it rearward. Operating voltages for the traveling wave tube may be measured as described below. Various circuit voltages are indicated on the schematic.

Helix: Helix and Anode voltages relative to cathode are available at tip jacks on rear cover. CAUTION: Use high resistance, ungrounded DC voltmeter, HIGH VOLTAGES EXIST ON TERMINALS.

The Grid and Heater voltages may easily be checked at terminal strip TS1. Use a high resistance DC voltmeter insulated from ground in making measurements. Refer to the schematic diagram and check out sheets for correct values and polarity.

If tubes have been tested and found to be normal, and supply voltages are incorrect, it is recommended that power be disconnected and faulty components located by a systematic resistance check.

For access to chassis components remove right handle side and cover side. CAUTION: Use heat sinks during soldering operations on transistors and diodes.

4-4 BLOWER REPLACEMENT

Remove dust screen, L. H. handle and cover sides, remove four mounting screws (6-32).

Unsolder blower leads. Blower may now be removed. In reassembly follow reverse procedure.

4-5 TRAVELING WAVE TUBE REPLACEMENT

1. Remove top dust screen.

2. Disconnect RF connectors from TWT.
3. Disconnect TWT electrode leads from terminal strip TS1.
4. Remove L. H. handle and cover side.
5. Remove four mounting screws holding TWT to deck and remove tube.
6. Follow reverse procedure in installing new tube.

4-6 OPERATION AFTER TWT REPLACEMENT

After the replacement of the TWT only the GRID CALIB control will need readjustment.

1. Before turning on power, set panel controls:

   GAIN-POWER to MIN
   HELIX to value stated on new tube data sheet
   METER switch to HELIX

2. Turn on power and allow instrument to warm up at least five minutes.
3. With High Voltage OFF , turn GAIN-POWER to MAX and set grid voltage with GRID CALIB control to value stated on new tube data sheet. May be measured between terminals 4 and 7 on terminal strip TS1.
4. Now proceed as in INITIAL OPERATION, Paragraph 3-2.

4-7 TRAVELING WAVE TUBE WARRANTY

See Tube Warranty and Replacement Procedure sheet at rear of manual.

4-8 WARRANTY

ALFRED products are warranted against defects in workmanship and materials. This warranty is limited to repair or replacement of products or parts (except tubes, transistors, and batteries) which prove defective within one year after delivery to original purchaser. ALFRED ELECTRONICS is not liable for consequential damage.

RAYTHEON COMPANY
MICROWAVE & POWER TUBE DIVISION
WALTHAM 54, MASSACHUSETTS

TWT OPERATING INSTRUCTIONS

UTION

der that the periodic permanent magnet focusing field of the TWT affected by shunting effects and by other magnetic fields, the wing magnetic isolation should be maintained:

2" from any magnetic material
4" from any magnet - This is a minimum dimension

NG

d air cooling across the collector fins is required to maintain the shell temperature below the specified maximum. An air flow of 5 cfm fficient under normal conditions.

R

volt heater supply, either a.c. or d.c., should be used. It is mended that one side of the heater be tied directly to the cathode event high heater-cathode difference of potential. This potential rence should not exceed 90V under any conditions.

aximum life and optimum performance the operating heater voltage be 6.3V $\pm$ 5%. The tube warranty does not apply to operation outside is heater voltage range.

the cathode and heater are normally operated at approximately 1800V 00V below ground, a well-insulated heater supply should be used.

ix overload should be provided to cut-off the anode voltage when current reaches 3 mA. This precaution prevents the possibility of burn-out.

Waveguide Output Tubes

There is a special terminal provided on the waveguide of the tube for application of the helix voltage.

Coaxial Output Tubes

Application of the helix voltage must be made to the center conductor of the coaxial connector. This may be accomplished by use of a coaxial monitor tee. Since the coax center conductors will be electrically hot after introduction of the helix voltage, DC blocks must be used at the input and output connector to prevent damage to the external circuitry and shocks to operating personnel. Monitor tees and DC blocks are commercially available.

l-regulated power supply should be used for the helix voltage to nt amplitude and phase modulation of the rf output.

CTOR VOLTAGE

egative high voltage should be connected to the cathode lead and
csitive high voltage connected to the collector-shell lead. The
ctor-shell should be grounded to reduce shock hazard.

VOLTAGE

recommended that the anode be run at a slightly higher potential than
elix. The recommended values are given on the enclosed test sheet.
eason for this difference in potential is to provide ion drainage
from the cathode for increased tube life.

VOLTAGE

rid voltage recommended on the enclosed test sheet refers to the
tial of the grid relative to the cathode.

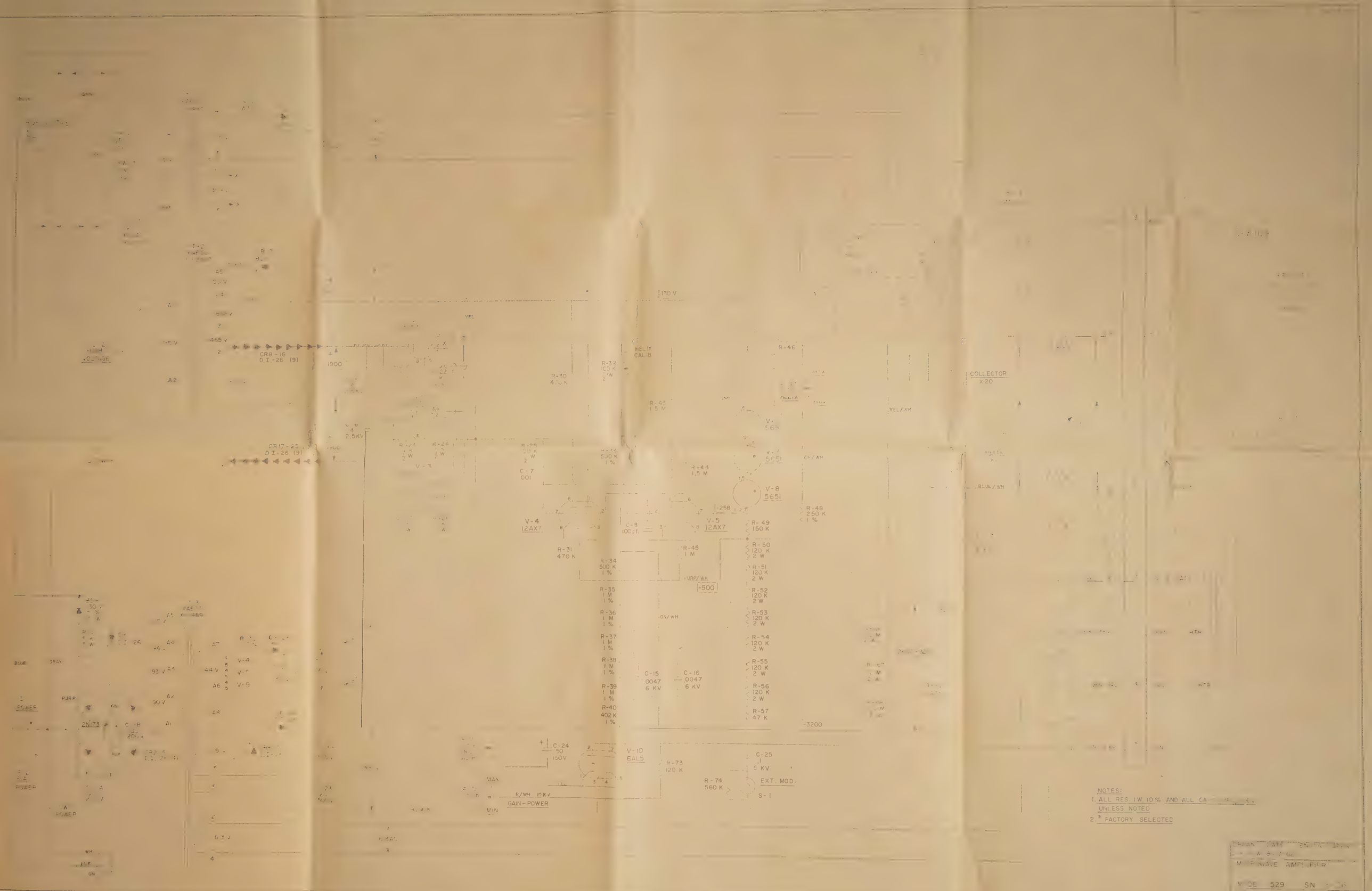
ON PROCEDURE

oltage turn-on sequence is as follows:

1. Heater
   Wait 60 seconds minimum
2. Grid voltage of -300V
3. Collector, helix and anode voltages
4. Reduce grid voltage to recommended
   operating level

turn-on procedures are available. Please contact manufacturer.

sure proper tube life, and in order to stay within the limits of the
nty, it is necessary to operate the tube in accordance with the above
mendations.



NOTES:
1. ALL RES. 1W, 10% AND ALL CA[illegible] UNLESS NOTED
2. * FACTORY SELECTED

[illegible] DATE [illegible]
A 8-7-62
MICROWAVE AMPLIFIER
MODEL 529 SN [illegible]

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GENERAL INFORMATION ON TRAVELING-WAVE TUBES

Introduction

Engineers who design and build circuits which use conventional low frequency vacuum tubes usually have at least a speaking acquaintance with the theory upon which these tubes operate. In designing their circuits or in deciding which type of tube to use, careful use is made of the various characteristic curves associated with the tubes. It is the purpose of the following brief discussion to similarly acquaint the applications engineer with the simple theory of the operation of the traveling wave tube and to familarize him with the various characteristic curves which describe its operation. From this discussion, it is hoped that the data sheets contained in this catalog may take on added meaning and that a better understanding of the basic functions of the traveling wave tube may be obtained.

Microwave Amplification

As the microwave region of the radio frequency spectrum has come into practical engineering use, engineers have been constantly on the lookout for devices which could function as better amplifiers and oscillators. In the frequency range above a few hundred megacycles conventional vacuum tubes no longer amplify properly because the period of one cycle of the radio frequency wave approaches the time it takes the electrons to travel from cathode to anode within the tube. As a result the amplification factor of the tube decreases with increasing frequency until no useful gain can be obtained. This is known as the transit time effect.

The first devices which served as practical amplifiers above a few hundred megacycles actually made use of transit time effects. These devices are known as klystrons and became useful primarily as oscillators although they are also capable of acting as amplifiers. Klystron amplifiers are capable of giving high values of amplification, but they have one serious limitation for many applications. They are relatively narrow band devices; having usually no more than a few megacycles bandwidth between half-power points. Tuning of the amplifier to different frequencies requires a mechanical adjustment. The klystron is, however, the forerunner of a whole general class of microwave electron devices which utilize transit time effects in electron beams. This general class of devices includes the traveling wave tube.

A klystron is a narrow band device because it involves the use of a very sharply resonant, high-impedance tuned circuit. It is necessary for a klystron to use such a circuit because interaction takes place with the electrons over only very short

physical distances and it must develop high electric fields to have efficient interaction with the electrons. However, it was reasoned that one might obtain a very broadband amplifying device if one used a low-impedance, broadband circuit which developed relatively small electric fields but which interacted with the electrons over a long physical distance. Such is the basis on which the traveling wave tube works and this basic concept has led to a wide range of devices which are useful as broadband amplifiers and oscillators in the microwave region.

The traveling wave tube is basically capable of giving high values of amplification over wide frequency ranges without requiring the change of any mechanical tuning mechanism or the variation of any voltages or currents applied to the tube. Power amplification greater than 10,000 (ie., 40 db gain) over a 2:1 frequency range has been obtained with this type of tube. The actual number of megacycles covered by such tubes can be a staggering figure. An operating bandwidth of 2000 megacycles has been obtained in one typical tube type; 7000 megacycles has been obtained in another.

Tubes can be built which emphasize various special characteristics. For instance, tubes can be built which have low noise properties, or high power output, or controlled variations of gain with frequency. Many special tubes have been designed and built for particular applications.

Simple Description of Theory of Operation
(Forward-wave Helix Type Amplifier)

One of the simplest circuit elements which satisfies the broadband low-impedance circuit requirement of the traveling wave tube is a simple helical transmission line. On this so-called helix, the radio frequency energy essentially travels at the velocity of light along the wire from which the helix is wound. But since the wire and the energy follow this helical path, the actual progress of the energy along the axis of the helix is at some fraction of the velocity of light. This velocity is determined by its dimensions (ie., its circumference and pitch) and by the dielectric loading due to the structure which supports the helix. The fields associated with this "slow-wave" extend outward and inward into the regions adjacent to the helix and it is into these regions that electrons are sent to interact with the waves.

If electrons are sent along the axis of the helix at essentially the same velocity as the waves, an interaction between waves and electrons occurs wherein the electrons become bunched and then become packed into tighter and tighter bunches as the electrons progress down the helix. Simultaneously, the radio frequency fields on the helix increase in magnitude as they progress down its length. The increase in energy of this "growing wave" is just balanced by a decrease in the average kinetic energy of the electrons in the beam. In other words, the electrons on the average have been slowed down and have given up just enough energy by this slowing down process to account for the increasing energy or power level in the waves on the helix.

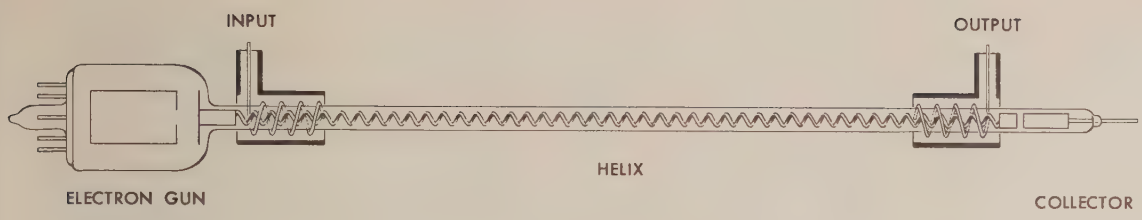

FIG. 1

Schematic View of Traveling-Wave Tube

In practice, the electron beam is formed in a gun and is focused down the center of the helix to a collector electrode on the farther end (see Figure 1). The velocity of the electrons is determined by the voltage difference between the cathode in the electron gun and the helix, and this is adjusted to give the electrons just the right velocity for interaction with the waves. The signal to be amplified is coupled onto the end of the helix nearest the electron gun and propagates along the helix in the same direction as the electron beam. Because of the interaction, the fields on the helix grow exponentially with distance and these amplified waves are coupled off of the helix at the end farthest from the electron gun. The devices which couple the energy on and off the helix at its beginning and end are connected to the input and output transmission lines. The electron beam that is formed in the gun is maintained in a tight pencil beam throughout the length of the tube by the confining forces of a longtitudinal magnetic field which surrounds the tube.

The devices which couple the energy onto and off of the helix are special directional couplers which are in themselves helices. These helices, which are outside of the vacuum envelope of the tube, are matched to the input and output coaxial transmission lines. They are capable of transferring most of the energy from the lines to the main helix, which is inside the vacuum envelope, without having to make physical contact to the helix. These "coupled helix matches" have the additional advantage that they have very wideband transfer characteristics and are capable of presenting a standing-wave ratio to the coaxial transmission line of 1.5:1 or less.

Specific Characteristics

In the following sections, the various characteristic curves that are encountered in operation of the traveling wave tube are shown and discussed.

Helix Voltage vs. Frequency

Usually a helix will be designed such that the "slow-waves" travel at a velocity in the range of 1/10 to 1/30 of the velocity of light. If the velocity of the waves is examined as a function

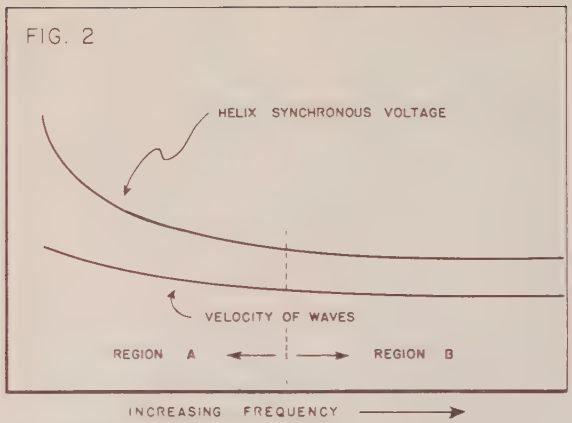

FIG. 2 PHASE VELOCITY OF THE WAVES AND SYNCHRONOUS HELIX VOLTAGE AS A FUNCTION OF FREQUENCY.

of frequency it is found a helix will have a general characteristic curve similar to that shown in Figure 2.

There is a region A where the velocity of the waves varies as a function of frequency, and there is a region B where the velocity of the waves is essentially independent of frequency. It is in this region B, known as the "non-dispersive region", where a broadband amplifier is normally operated.

As mentioned before, it is necessary to have the electrons travel down inside the helix at essentially the same velocity as the waves (synchronous velocity) in order to obtain the growing wave interaction. Thus if the velocity of the wave varies as a function of frequency, the velocity of the electrons must also be varied so that interaction is maintained. Since the velocity of the electrons is determined by the voltage difference between the cathode and the helix, there is also a characteristic curve of synchronous helix voltage as a function of frequency which is shown in Figure 2.

The reason why a helix type traveling wave tube can amplify over wide bandwidths without changing helix voltage can now be easily seen. In the region B, the non-dispersive region, the synchronous voltage of the electrons is essentially independent of frequency. That is, the helix voltage which gives the desired interaction between the waves and electrons can be fixed at one value and this will be the correct value to provide interaction and amplification over a wide range of frequencies.

Gain vs. Helix Voltage

To obtain the greatest interaction between the waves and the electrons and thus the greatest amplification, the helix must be operated at synchronous voltage. If the helix voltage is varied away from synchronism, the gain will decrease as shown by the curve in Figure 3 which is parabolic in shape.

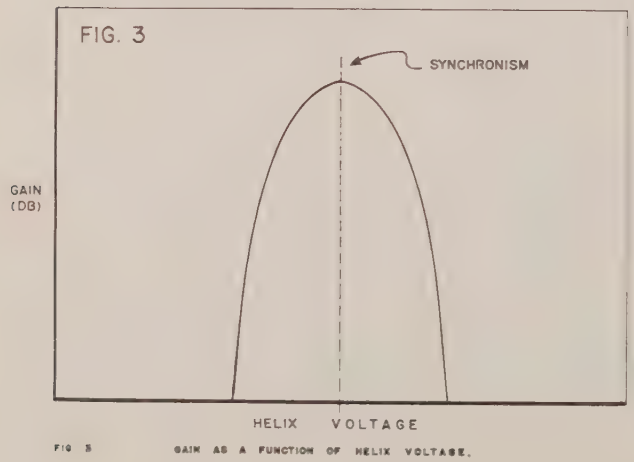

FIG. 3 GAIN AS A FUNCTION OF HELIX VOLTAGE.

Gain and Power Output vs. Frequency

Figure 4 shows a typical plot of gain vs. frequency for a fixed value of helix voltage. Small signal gain is obtained

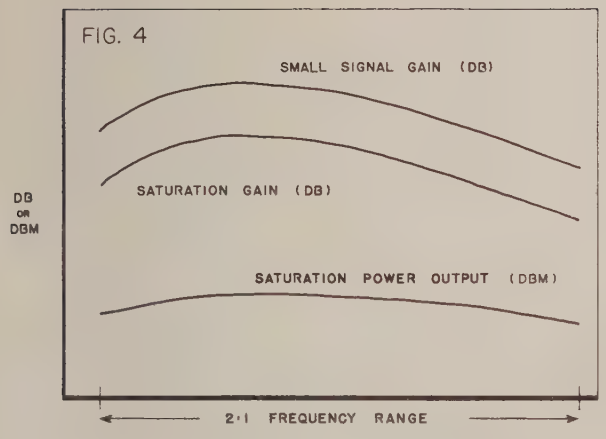

FIG. 4 GAIN AND POWER OUTPUT AS A FUNCTION OF FREQUENCY.

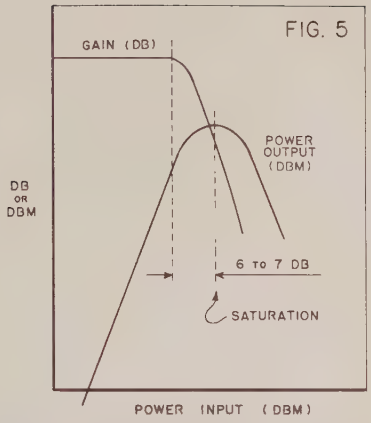

FIG. 5 GAIN AND POWER OUTPUT VS. POWER INPUT AT A FIXED FREQUENCY.

for all values of input signal level except those which drive the tube near its maximum or saturation power output. Saturation gain is the gain obtained when the tube is driven to its maximum or saturation power output. It is seen that the gain and power output curves generally have a maximum near the center of the band and that the curves droop off towards the band ends.

Power Output and Gain vs. Power Input

Figure 5 shows a typical variation of power output and gain vs. power input at a fixed frequency. The amplifier is linear until power input is within 6 to 7 db of the value which drives the amplifier to saturation. At this point the power output curve begins to droop over, and gain of the tube begins to decrease. At saturation the power output is a maximum and the gain has decreased to a value which is called saturation gain. As the tube is driven beyond saturation the power output drops off and gain continues to decrease. To obtain maximum power output from an ordinary traveling wave tube, just the right amount of power input must be applied. The saturation region does not exhibit the leveling off or flat saturation characteristic that is found in conventional low frequency amplifier tubes.

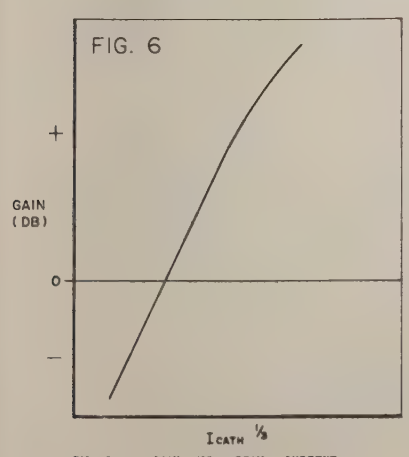

FIG. 6 GAIN VS. BEAM CURRENT

Gain vs. Beam Current and Grid Voltage

Figure 6 shows that the gain at any fixed frequency is essentially a function of the 1/3 power of the beam current and decreases as beam current is decreased. Figure 7 shows that as the grid electrode is made negative with respect to the cathode, the gain of the tube decreases. This results from the fact that operating the grid negative with respect to the cathode causes the beam current to decrease.

If the beam current is decreased below a certain value as shown in Figure 6, the gain of the tube measured in db becomes

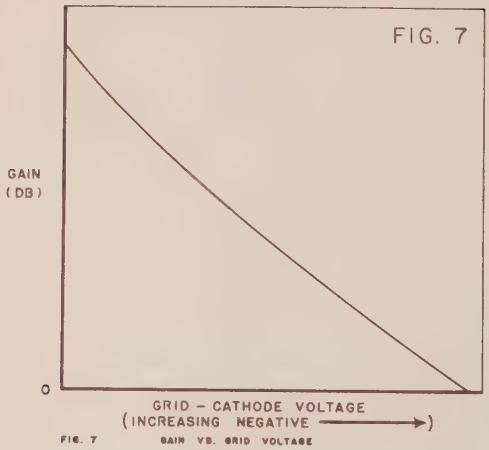

FIG. 7 GAIN VS. GRID VOLTAGE

negative, ie., the tube is acting as an attenuator. If the beam current is reduced to zero, the net "cold" attenuation of the tube is available. The total change in signal output level as beam current is decreased from its normal value to zero is equal to the sum of the net gain of the tube plus the cold attenuation. This can approach a variation in signal level of about 100 db. This is accomplished merely by varying the control grid voltage.

Special Characteristics

Low Noise Amplifiers

On a typical low power amplifier one may find a noise figure of 20 db. Certain applications require lower noise figures than this. Techniques are available in electron gun design whereby the "shot noise" in the beam can be "de-amplified" before it reaches the beginning of the helix. Special purpose tubes built in this fashion have reached noise figures as low as 6 db.

Narrow Band Amplifiers

Where an application does not require extremely wide bandwidths, tubes have been built which operate in the dispersive region of the tube characteristics where the velocity of the waves varies as a function of frequency (see Figure 2). In this region operation at a fixed voltage leads to amplification over only a relatively narrow band of frequencies. Extremely high values of gain (eg. 60 to 70 db gain) have been obtained because the problem of controlling spurious oscillations is much simplified since the tube exhibits gain over only a relatively narrow band.

Special Gain Variation

Sometimes special requirements are imposed on the gain variation of the tube as a function of frequency. Tubes have been built which exhibit an essentially constant value of gain across the band. Others have been built which have linearly increasing gain with frequency. Various other combinations are also possible.

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MEASUREMENT TECHNIQUES

As traveling wave tubes have come into more common use, the need has become apparent for a clarification of the various measurement techniques involved in an evaluation of the tube characteristics. Since the traveling wave tube is a very broadband device the emphasis must be upon broadband, untuned measuring techniques and test equipment. Otherwise, much time will be lost in the repetitive and laborious adjustment and tuning of narrow band devices to make point by point measurements across wide frequency ranges.

It will be noticed that the emphasis on measuring equipment has been placed upon coaxial systems. This is done, obviously, because of the inherent wideband properties of coaxial test equipment. Waveguide equipment is used only where equivalent coaxial equipment is not available or will not do an equivalent job.

The various types of broadband test equipment commonly used are listed below:

1. Self-tracking tunable signal generator with calibrated power output.
2. Untuned coaxial crystal detector.
3. Untuned coaxial bolometer or thermistor mount with self-balancing power bridge.
4. Broadband coaxial fixed attenuator.
5. Coaxial switch (SPDT).
6. Coaxial slotted section (for VSWR measurement) with untuned detector.
7. Coaxial or waveguide directional coupler.
8. Fluorescent noise source.

The characteristics to be measured comprise essentially the following list.

1. Gain
2. Power Output
3. Standing Wave Ratio or Reflection Coefficient
4. Insertion Loss
5. Noise Figure

PROCEDURES

A. Measurement of Gain

The most rapid and satisfactory method of measuring gain is to make an insertion gain measurement using the substitution method. This method does not require a knowledge of the detector characteristics nor an absolute power calibration of the signal generator. Its accuracy depends only upon the calibration accuracy of the output attenuator of the signal generator.

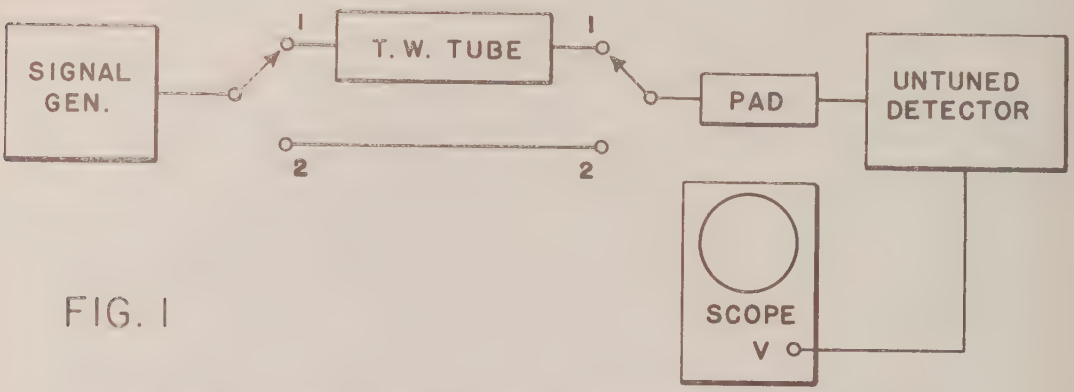


FIG. 1

BLOCK DIAGRAM OF GAIN MEASUREMENT SET-UP

As shown in the block diagram of Figure 1, the output of the signal generator (which has a matched 50 ohm output) is fed to the input of the tube through a coaxial single-pole double-throw switch. The output of the tube is fed through another coaxial switch and at least a 6 db coaxial fixed attenuator pad to the untuned detector. The pad can be eliminated if the detector is matched. The output of the detector is fed to the vertical deflection channel of an oscilloscope. The tube is by-passed when the switches are thrown to the other position.

Procedure:

Apply pulse or square wave modulation to the signal generator. With the tube operating and the switches in position 1, the output attenuator of the signal generator is adjusted to give some convenient deflection on the scope. This is attenuator reading 1. The switches are then thrown to position 2 and the attenuator readjusted to give the same deflection on the scope. This is attenuator reading 2. The insertion gain of the tube is then the difference of the attenuator readings 1 and 2 measured in db.

Precautions:

1. Both the signal generator and the detector must present good impedance matches as seen by the switch. If they are not matched, then reflection losses can give up to several

db error in gain. This is the reason for the pad ahead of an unmatched detector. A 6 db pad guarantees a VSWR of at most 1.5:1.

2. The switch used must have a low VSWR and very low crosstalk. Crosstalk is the stray feedthrough from input terminal to output terminal of the DPDT switch combination through the unused channel of the switch. Crosstalk ratio is measured by disconnecting the tube from terminals 1, and measuring the difference in signal generator attenuator reading with the switches in position 1 and position 2 for the same deflection on the scope. This crosstalk ratio should be at least 20 db greater than the gain of the tube to be measured. This prevents regenerative feedback around the switch which will give errors in gain measurement. If the crosstalk ratio is greater than about 45 db, it probably cannot be measured with the setup of Figure 1. See section D on insertion loss measurement.

3. If small signal gain is to be measured, care must be taken that the output power level of the tube is at least 10 db below the saturation power level. This eliminates errors due to the decreasing gain characteristic of the traveling wave tube in the region near saturation.

B. Measurement of Power Output

When power measurements are to be made over wide frequency ranges, it is convenient to use broadband (untuned) bolometer or thermistor mounts as power detectors. When these mounts are operated in conjunction with a self-balancing wattmeter bridge they provide a convenient system for the measurement of absolute power.

If the power level to be measured is greater than the maximum allowable power input to the mount, then it is necessary to insert a calibrated attenuator pad ahead of the mount. The most convenient type of pad to use is the resistive film type which has attenuation characteristics which are essentially independent of frequency. Care must be taken not to exceed the maximum input rating of the attenuator.

If power levels to be measured are greater than the rated dissipation of standard attenuator pads, then a directional coupler must be placed on the output of the tube. The main arm of the coupler is terminated with a broadband load and the power detector with appropriate pads is placed in the auxiliary arm of the coupler. Broadband coaxial directional couplers with coupling ratios of 10 and 20 db from main arm to auxiliary arm are available.

If gain measurements are to be made in conjunction with the power measurements then the power output of the signal generator must be calibrated using its power monitor at each

frequency. For the sake of accuracy, the power output reading of the signal generator should be initially checked using the bolometer mount and the wattmeter bridge at least over the range of power levels that the bridge can accurately read. If care is taken to check the calibration of the attenuator pad and the signal generator, then the small signal gain measurements obtained with this equipment should check with small signal gain measurements made by the method of section A.

If all power measurements are recorded in terms of dbm (ie., db with respect to one milliwatt), then the readings of the power bridge, the attenuator (in db) and the signal generator need be merely added and subtracted to obtain power output and gain. Conveniently, most signal generators and power bridges are calibrated in dbm as well as milliwatts.

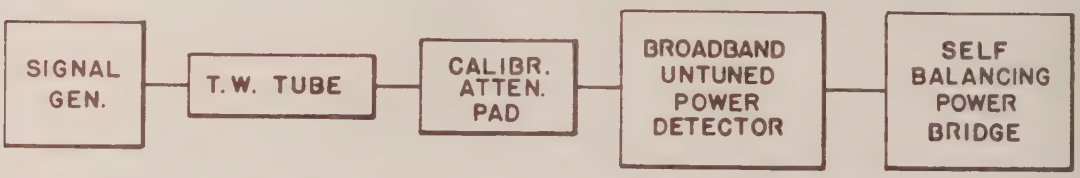


FIG. 2 BLOCK DIAGRAM OF POWER MEASURING SET-UP

Figure 2 shows the block diagram of the power measurement setup. The power output is then given by the equation:

$$P_{out}\ (dbm) = \text{Pad Attenuation (db)} + \text{Ratio of Directional Coupler (db)} + \text{Power Bridge Reading (dbm)}$$

The gain of the tube is given by the equation:

$$\text{Gain (db)} = P_{out}\ (dbm) - P_{in}\ \text{from Sig. Gen. (dbm)}$$

The above gain measurement is valid not only for small signal gain, but also for gain measured in the saturation region and beyond.

C. Measurement of Standing-Wave Ratio or Reflection Coefficient

For direct measurement of Voltage Standing-Wave Ratio (VSWR) the coaxial slotted line is the simplest. To speed up broadband measurements, however, it is essential to have an untuned detector on the slotted line.

For situations where it is necessary to examine the VSWR continuously over a wide frequency range and where fast checks are required such as on production test setups, the slotted line type of measurement becomes prohibitively time consuming and laborious. For such situations, the measurement of reflection coefficient through the use of directional couplers is recommended. Two directional couplers connected so that one will give an output proportional to the incident wave and the other an output proportional to the reflected wave from the

load can be used. These two outputs can be detected and compared with a ratiometer to give a direct reading of reflection coefficient. The reflection coefficient can be converted to equivalent VSWR if necessary. The higher the accuracy required in the measurement of reflection coefficient, the higher the directivity of the directional couplers must be. In waveguide, directivity greater than 40 db over the waveguide range can be obtained which allows measurement of reflection coefficient of 0.1 with an accuracy of plus or minus .02. This means that a load VSWR of 1.2 will give an indicated reading between 1.15 and 1.25. A waveguide to coaxial transition can be used to adapt the reflectometer to coaxial systems. In this case, the residual reflection in the transition limits the accuracy at low VSWR.

Using such a reflectometer setup, once the initial calibration is performed it is necessary only to tune the signal generator across the frequency range and the reflection coefficient values read directly. An excellent detailed discussion of this method, its errors and limitations, is given in the Hewlett-Packard Journal, Volume 6, Number 1-2, Sept.-Oct., 1954.

Even faster measurements can be made when a swept oscillator is employed. Reflection coefficient can be displayed directly on a scope as a function of frequency and the measurement can be made at a glance.

D. Measurement of Insertion Loss

It is often necessary to measure insertion loss in the range of 40 to 100 db (eg., the measurement of the cold loss of a traveling wave tube) over a wide range of frequencies. Such a measurement cannot be made with 1 milliwatt signal generator and a broadband detector as this type of system does not have the power levels nor the sensitivity to measure much more than 45 db insertion loss. Such a wideband measurement can be made quickly and easily with the use of one or two traveling wave tubes as amplifiers. Use of a traveling wave tube with a noise figure of 20 db ahead of the detector gives a sensitivity into a broadband detector of the order of -65 to -75 dbm. This alone allows the measurement of insertion loss of 65 to 75 db. Further, if the output of the signal generator is amplified to the power level of one watt (+ 30 dbm) by the use of a medium power traveling wave tube, the total insertion loss then measurable becomes 95 to 105 db. The only adjustment necessary as frequency is changed across the band is the tuning of the signal generator since the traveling wave tubes are broadband untuned devices. The insertion loss measurement can be made in the same manner as the insertion gain measurement shown in Figure 1 except for the addition of the amplifiers before and after the switches. Commercially available switches when connected as shown in Figure 1 have been measured to have a combined crosstalk ratio in excess of 120 db which, of course, eliminates any crosstalk error in insertion loss measurements in the range of 95 to 105 db.

E. Measurement of Noise Figure

Where one is interested in measuring noise figure at a number of frequencies throughout a wide frequency band, the best method employs a fluorescent tube noise source and a superheterodyne receiver with a second detector which is square law (ie., a power detector). If noise figure does not vary too rapidly with frequency, a simple receiver can be used which employs only an untuned crystal mixer, a local oscillator, a 30 mc I.F. strip and a power detector. Note that no preselection or mixer tuning is used. Without a preselector, the receiver will respond equally well to the signal frequency and to the image frequency. With a 30 mc I.F. amplifier, these two frequencies will be only 60 mc apart, and if noise figure is not a rapid function of frequency then the measured noise figure will be an average of the true values at two frequencies 60 mc apart. This is accurate enough for most purposes. If noise figure varies so rapidly that it will be appreciably different at two frequencies spaced 60 mc, then preselection is necessary.

The noise figure of an amplifier is defined as the ratio of signal to noise ratio at the input of the amplifier to signal to noise ratio at the output of the amplifier.

$$N.F. = \frac{(S/N)in}{(S/N)out} \quad \text{(power ratio)}$$

When the measurement is made according to the method outlined below, using a noise source whose level is 15.8 db above thermal noise, the above equation becomes:

$$N.F. = \frac{37k}{\frac{P_1}{P_2} - 1} \quad \text{(power ratio)} \qquad (1)$$

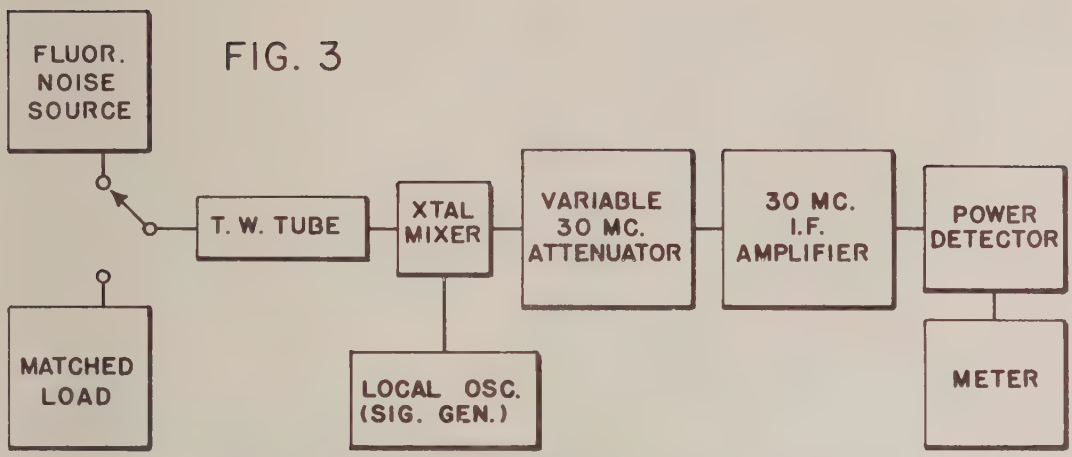
where P_1 and P_2 are defined in the measurement procedure below.
k is a number smaller than 1.0 which accounts for any cable loss between the noise source and the tube. It is the cable loss in db converted to a power ratio. (eg., for cable loss = 1 db, k = .794)

When a fluorescent noise source is used it is not necessary to know the effective RF noise bandwidth of the receiver.

Procedure:

The tube to be measured is connected into the setup shown in Figure 3. The power detector in the receiver may take the form of a bolometer or a thermistor operating into a self balancing wattmeter bridge, or it may be a thermocouple whose output is connected to a microammeter.

FIG. 3



SET-UP FOR MEASURING NOISE FIGURE

1. With tube operating and local oscillator tuned to the desired frequency, switch tube input to the fluorescent noise source.

2. Adjust variable 30 mc attenuator until the reading on the output meter is approximately full scale. This is reading P_1.

3. Switch tube input to the matched load. The reading of the output meter is P_2.

4. Insert values for P_1 and P_2 in equation (1) for noise figure. Noise figure in db is obtained by merely converting this number to db.

Precautions:

The accuracy of this measurement is based upon the assumption that the receiver is linear. This will be true if the local oscillator signal is large enough to produce linear mixing and if the I.F. amplifier is operated in the linear portion of its characteristics.

The measurements should be taken quickly enough so that power meter drift will not effect readings.

-- L. A. Roberts

ALFRED

Tube Warranty and Replacement Procedure

Tube Replacement

All TWT and BWO tubes furnished in ALFRED instruments are available from ALFRED ELECTRONICS or the tube manufacturer for either warranty or out-of-warranty replacements. Current prices are given in the Replacement Tube Price List. In general, they are about 10% higher than the manufacturers' list price to allow for ALFRED retest to assure complete specification compliance.

Tube Warranty

On ALFRED supplied TWT and BWO tubes used in catalog instruments, ALFRED ELECTRONICS extends the full warranty given by the tube manufacturer current at time of replacement and, in addition, offers the following minimum warranty:

> "Tubes are warranted to meet specifications against defects in workmanship, materials, and construction for a period of one year or a rated number of heater hours, whichever expires first. If a defect occurs during the warranty period, a prorated adjustment will be made based on the list price of the tube and the percentage of rated heater operating hours or the one year period."

Rated hours are:

Type	Power	Warranty
TWTA	1 to 20 mw	2000 hours
TWTA	100 mw to 1 w	1000 hours
TWTA	2 to 10 w	500 hours
TWTA	(low N.F. 10 to 15 db)	1500 hours
BWO	3 to 10 mw	~~500~~ 1000 hours

If a tube should fail within the first 50 hours of heater operation and within two months after shipment, the tube will be replaced at no charge.

RETURN AUTHORIZATION

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

Return Procedure

In case of tube or instrument failure, please contact the factory or your local sales representative for advise or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely all around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

Repairable Tube

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

End of Life Replacement

Near the end of tube life, or for other reasons, if tube performance is deteriorating slowly, it may be desirable to continue operating with the defective tube while a replacement tube is being processed. In this case ALFRED ELECTRONICS should be notified as soon as possible of the condition of the tube and a purchase order issued for a replacement tube at list price. Only if the defective tube and service report are received within 3 weeks after date of shipment of the replacement tube, will warranty credit be based on the date defective TWT notification was received at ALFRED ELECTRONICS. The replacement tube is the property of the buyer. However, should the defective tube be repairable, a purchase order should be issued to cover the repair charge.

Warranty Credit

Any applicable credit allowed under the terms of this warranty applies only toward the future purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of 6 months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF Cables

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair, or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge.

Special Conditions

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

11/21/62

ALFRED ELECTRONICS

Service Report

Instrument Model _____ Serial No. _____ Date Received _____

TW/BWO Tube Type _____ Serial No. _____ Date Received _____

Date First Tested _____ Date Placed in Service _____ Date of Failure _____

Total Number of Hours of TWT/BWO Heater Operation _____

1. Was operation normal just prior to failure? Yes _____ No _____
2. If not, what was done to adjust it? _____
3. Has proper cooling been maintained during tube operation? _____
4. Did helix overcurrent tripout occur? _____
5. Was environment normal? (specify) _____
6. Symptoms – (describe failure) _____
7. Operating conditions at time of failure (indicate any unusual conditions) _____
8. Name of person to contact regarding evaluation of failure _____

Telephone No. _____ Signature _____

Title _____

Date _____

ALFRED

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Tube Warranty

On ALFRED supplied TWT and BWO tubes used in catalog instruments, ALFRED ELECTRONICS extends the full warranty given by the tube manufacturer current at time of replacement and, in addition, offers the following minimum warranty:

> "Tubes are warranted to meet specifications against defects in workmanship, materials, and construction for a period of one year or a rated number of heater hours, whichever expires first. If a defect occurs during the warranty period, a prorated adjustment will be made based on the list price of the tube and the percentage of rated heater operating hours or the one year period."

Rated hours are:

Type	Power	Warranty
TWTA	1 to 20 mw	2000 hours
TWTA	100 mw to 1 w	1000 hours
TWTA	2 to 10 w	500 hours
TWTA	(low N.F. 10 to 15 db)	1500 hours
BWO	3 to 10 mw	~~500~~ 1000 hours

If a tube should fail within the first 50 hours of heater operation and within two months after shipment, the tube will be replaced at no charge.

RETURN AUTHORIZATION

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

Return Procedure

In case of tube or instrument failure, please contact the factory or your local sales representative for advise or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely all around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

Repairable Tube

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

End of Life Replacement

Near the end of tube life, or for other reasons, if tube performance is deteriorating slowly, it may be desirable to continue operating with the defective tube while a replacement tube is being processed. In this case ALFRED ELECTRONICS should be notified as soon as possible of the condition of the tube and a purchase order issued for a replacement tube at list price. Only if the defective tube and service report are received within 3 weeks after date of shipment of the replacement tube, will warranty credit be based on the date defective TWT notification was received at ALFRED ELECTRONICS. The replacement tube is the property of the buyer. However, should the defective tube be repairable, a purchase order should be issued to cover the repair charge.

Warranty Credit

Any applicable credit allowed under the terms of this warranty applies only toward the future purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of 6 months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF Cables

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair, or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge.

Special Conditions

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

11/21/62

ALFRED ELECTRONICS

Service Report

Instrument Model _____ Serial No. _____ Date Received _____

TW/BWO Tube Type _____ Serial No. _____ Date Received _____

Date First Tested _____ Date Placed-in Service _____ Date of Failure _____

Total Number of Hours of TWT/BWO Heater Operation _____

1. Was operation normal just prior to failure? Yes _____ No _____
2. If not, what was done to adjust it? _____
3. Has proper cooling been maintained during tube operation? _____
4. Did helix overcurrent tripout occur? _____
5. Was environment normal? (specify) _____
6. Symptoms – (describe failure) _____
7. Operating conditions at time of failure (indicate any unusual conditions) _____
8. Name of person to contact regarding evaluation of failure _____

Telephone No. _____ Signature _____

Title _____

Date _____

SHIPMENT DAMAGE CLAIM

The instrument should be tested as soon as it is received. If it fails to operate properly or is damaged in any way, a claim must be filed with the carrier. Have carrier agent inspect damage to instrument and packing crate and forward us a copy of his written report. You will then be advised of replacement or repair arrangements and disposition of the equipment. Please include model number, type number and serial number when referring to this instrument for any reason.

WARRANTY

ALFRED products are warranted against defects in workmanship and materials. This warranty is limited to repair or replacement of products or parts (except tubes, transistors, and batteries) which prove defective within one year after delivery to original purchaser. ALFRED ELECTRONICS is not liable for consequential damage.

If any fault develops:

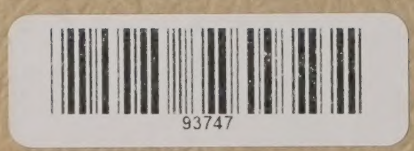
1. Notify us, giving full details of the difficulty, including the model number, type number and serial number. Upon receipt of this information you will be sent service instructions or shipping data.

2. Upon receipt of shipping instructions forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins when instrument is not covered by this warranty.

PACKING

The instrument should be packed in the original carton. If unusable or not available, use a wooden box with approximately three inches of excelsior or other shock-absorbing material surrounding the instrument. If desired, packing services of a local Transfer and Storage company may be employed.

10-12-62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